Capacity Management Requirements for Virtual Enterprises

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Abstract. Transformations in the marketplace have led manufacturing companies to focus on their core competences and compete through new forms of enterprise partnerships. A new concept of enterprise partnership is that of Virtual Enterprise wherein autonomous or independent companies come together to temporally address a specific market demand, by collaborating closely and presenting to the market as a single enterprise. A number of traditional operations management models or techniques need to be redesigned in order to cope with the demands brought by the implementation of the Virtual Enterprise concept.

This paper attempts to ascertain the understanding that exist about the concept of Virtual Enterprise as well as its associated managerial challenges. Then, focusing on the issues of manufacturing capacity management, the requirements for an effective deployment of this function in a Virtual enterprise environment are described.

Key words: virtual enterprise**,** enterprise collaborations, networked manufacturing.

1 Introduction

Partnerships between companies, although is not a recent phenomenon, is becoming more and more powerful strategy to succeed in today's business environment characterized by volatile and global markets, and increasingly demanding customers in terms of quality, price, and response time. In this environment, manufacturing companies now have to constantly introduce new, sophisticated, high quality products in a reduced time-to-market, and be able to respond rapidly to changes occurring in the marketplace. Meeting these new challenges is often beyond the capabilities of individual firms.

Industrial collaborations are not new, they have been well known for years even for decades. In the one-of-a-kind business, product-specific or project-specific, industrial co-operations are well introduced for years. However, the relevance, the need as well as the chances of successful enterprises co-operations have changed dramatically and will become more and more important in today's information society (Thoben and Jagdev, 2001).

Hence, increasingly companies are focusing on a small number of core competences and form collaborative networks, consisting of multiple and globally dispersed manufacturing facilities, in order to share risks and gain competitive power through different kinds of synergies.

As a result of this shift from one-site oriented manufacturing towards multi-site manufacturing networks, a new manufacturing paradigm has come into place - that of Virtual Enterprise. The concept of Virtual Enterprise can be defined as a temporary alliance of autonomous or independent companies linked by a communication infrastructure, and which come together to address a specific business opportunity by sharing resources, skills and core competencies. Virtual Enterprise is a powerful way of doing business since it allows partner companies to be agile, access to expertise, facilities and market niches with world-class level, which may not be achieved individually.

A number of existing operations management models or methodologies need to be redesigned in order to cope with the features and challenges posed by this new manufacturing paradigm. However, before this can be done, it is necessary to clearly understand the concept and fundamental problems associated to Virtual Enterprises. Thus, this paper intends to review the concept of VE and to identify its implications to a key area of operations management, specifically that of manufacturing capacity management.

The paper proceeds as follows. In section two conceptual issues on Virtual Enterprise are described through a review of relevant literature. Then, in section three some problems associated to the implementation of VEs are discussed. In section four, the requirements for capacity management in VE environments are identifies. Finally, in section five, conclusions and current directions for research are given.

2 Virtual Enterprise concept

2.1 Context

Manufacturing systems must be seen in the context of the total business and the associated key linkages of the business back through upstream (supplier chain) and forwards to downstream (distribution and customer chain). These chains can be more or less complex, concerning to the range and scope of collaborations, and often these chains take the forms of enterprise networks. Part of this evolution is described by Womack *et al.* (1991).

When two or more enterprises collaborate, they could form an enterprise network. Combining the best of everything allows the creation of an entirely customised product or service at low cost and with higher quality. Indeed, focusing on core competencies resulted in the outsourcing of all activities that were not considered to be of strategic importance to the organisation's market position (Jagdev and Thoben, 2001). Inter-organisational cooperation can thus be of strategic importance for those who wish to offer more and more sophisticated and complex products and to cover new markets exploring news opportunities and converting threats in potential market opportunities.

In a given enterprise network the needs of each node will vary depending on the primary focus of the collaboration and on the nature of the product or service provided. In a supply-chain, traditionally each chain member or node is a separate entity that may be highly integrated internally but with rigid business processes when viewed from the outside. Customer orders are passed up the chain through each partner and products then flow back down to the end customer in an opposite sequence.

In order to provide high levels of agility, it is necessary to combine features of a fully market-oriented organisation, such as legal independence of the entities and specialisation of functions, with features of co-operative forms of organisation, such as close collaboration involving

integration of information and trust between the participating entities. The concept of "virtual enterprise" responds fairly well to this challenge.

In fact, co-operative networks of companies can be made up of many different entities and various types of interaction between the participating entities may take place. Their co-ordination and the access and sharing of knowledge and information are becoming increasingly important. Moreover, setting up the network and managing it in an optimised way, balancing customer needs with increased performance along the whole network, may be a key factor for the competitiveness of a company. In particular, a lot of attention should be given to the design of effective methodologies and tools to support co-operation and collaboration, as applied to processes such as aggregate planning and customer order negotiation (Azevedo and Sousa, 2000).

Within the field of enterprises networks, can be identified three main types of collaborations : *Supply Chain, Extended Enterprise* and *Virtual Enterprise* (Jagdev and Thoben, 2001). While the concept of supply chains has been well established, extended and virtual enterprises are new paradigms reflecting the emergence of Information and Communication Technology (ICT) as the driver for this paradigm shift and the enabler for modern enterprise collaborations.

The *Supply Chain* is the collection of all components and functions associated with the creation and ultimate delivery of a product or service (Ratliff and Nulty, 1997). Supply chain management is the management of activities that transform raw materials into intermediate goods and final products, and that deliver those final products to customers.

The *Extended Enterprise* can be regarded as a kind of 'enterprise' which is represented by all those organisations, customers, suppliers and subcontractors, engaged collaboratively in the design, development, production and delivery of a product to the end user. Key suppliers and its information infrastructures become almost a part of the core company with frequent exchange of data and information (Browne *et al.* 1996).

The *Virtual Enterprise* is a new organisational paradigm as a response to the dynamic and globalisation of today's markets. In fact, it is the availability of ICT technologies that has given to enterprises entirely new platforms to collaborate efficiently. In literature it is possible to find several definitions and concepts related to virtual enterprises. The aim of next section is to present a review of some definitions and characteristics of the Virtual Enterprise described in the literature.

2.1 Definitions and Characteristics

A lot of research has been devoted to study issues related to organisation, co-operation and collaboration, sharing, control and compatibility of information within the context of operations of Virtual Enterprise (VE). Some authors define VE as a temporary network of independent organisations that jointly form an entity committed to provide a product or service in order to satisfy a market's opportunity and are full supported by ICT technologies. Thus they form, reconfigure and dissolve based on the market dynamics and the opportunities it provides.

In Globman21 (1999) it is stated that: "A VE is a customer solutions delivery system created by a temporary and reconfigurable ICT enabled aggregation of core competencies". Moreover, four features are identified as being distinctive characteristics of the VE:

- A temporary enterprise with the duration of a specific project – setting up a delivery system providing a customer solution;
- Alliance of core competencies assigned from different enterprises;

- Created in an attempt to obtain agility and speed;
- Enabled and supported by ICT.

In the X-CITTIC project, a VE is defined as subset of autonomous production units within a supply chain, which behave like a single company through strong co-operation and co-ordination toward mutual goals (Azevedo and Sousa, 1998). Camarinha-Matos et al. (1999) introduce a similar definition by describing a VE as temporary alliance of enterprises co-operating trough computer networks, and sharing skills or core competencies and resources in order to best satisfy business opportunities. Co-operation and networking are seen as two keywords in this definition. The authors state that in a VE, companies do not produce complete products in isolated facilities. Rather, they operate as nodes in a network of suppliers, customers, engineers, and other specialised service providers. In this network, co-operation is viewed as a key underlying aspect, involving sharing information and other resources, communication, inter-connection between producers and consumers, and collaborative activities.

Hardwick and Bolton (1997) view a VE as a consortium of companies virtually united to manufacture products together none could build alone, and in response to a worldwide business opportunity. They state that VE companies share costs, skills, and core competencies that collectively enable them to access global markets with world-class solutions. Electronic collaboration between companies through high-performance computer networks is regarded as one of the central characteristics of VE.

Hammer (2000) highlights the concentration on core competencies in VE by giving the example of Cisco Systems company. According to the author, this company focuses on two core processes – developing new products and selling products to customers – and allows the rest to be performed by other enterprises. A contract manufacturer assembles the products from parts made by suppliers, and a materials management company controls the inventory and delivers the final products to customers. Usually, the physical products received by the final clients never pass through Cisco Systems sites. The author concludes that in a VE, each member performs processes rather than produce complete products. This model differs from outsourcing, in which a company allows others to carry out nonessential functions. In a VE, he says, "… specialist firms perform critical processes – not because they're unimportant, but rather because they are so important that the original company can't afford to have them handled in a mediocre way".

Citing Mertens, Tuma (1998) state that the basic objective of a VE is to create a certain type of a "best of everything organization" by a synergetic combination of the core competencies of independent, specialized partners. He analyzed some industrial cases, and identified the following distinctive features of VE:

- Concentration on core competencies;
- Network orientation;
- Organizational flexibility;
- Extensive use of computer and telecommunication systems;
- Lack of hierarchies;
- Project character.

In Kanet et al. (1999) it is reported a definition given by Arnold et al. who claim that:

> *"A VE can be seen as an organization form in which a collection of legally independent enterprises, institutions, or single persons come together quickly to co-operate for a particular mission. There is shared understanding of business objectives. Each member*

brings to the co-operation its core competencies relevant to a mission. Typically, no formal management bureaucracy is established, and because of the need for speed, a great deal of trust must exist among members".

The concept of VE is close to that of Extended Enterprise (EE) and sometimes they are used indistinctly. However, although they share many common features they differ in some aspects, which are well described by Browne and Zhang (1999):

- In VE, the partnership purpose refers to temporary working together for projects or products, while in EE it concerns long-term business co-operation;
- VE is characterized by a dynamic organization of companies each one contributing with core competencies; contrarily, the EE is a stable organization of companies across the product value chain;
- The boundaries between partners are less blurring in VE than in EE;
- The organization type of VE is frequently project or niche market based, while the EE is generally product value-chain based;
- Normally a broker co-ordinate the co-operation in VE, while usually there is a manufacturer who co-ordinate the partnership in EE;
- The access to sophisticated information and communication technologies is more critical in VE than in EE for facilitating and enabling the co-operation.

Therefore, from the above reviewed definitions, it can be concluded that, though some minor divergences exist between the various authors' definitions, there is, however, a consensus on the most important features of the VE. Hence, summarizing, a VE is seen as:

- A transient organization created for a specific project;
- A combination of core competencies from autonomous or independent companies;
- An alliance of shared costs, skills, resources, markets and risks;
- A geographically distributed network;
- An enterprise partnership created with little contractual bureaucracy;
- Formed to foster flexibility and speed to market;
- Built with total focus on customer;
- Enabled and supported primarily by Information and Communication Technologies.

2.2 Virtual Enterprise life cycle

From a theoretical perspective, the life cycle of a VE can be divided into five generic phases: identification of business opportunity, formation, design, operation, and dissolution (Fig.1).

1- ***Identification*.** A broker or a prospective main contractor identifies a specific business opportunity or receive a direct request from a customer.
2- ***Formation*.** This phase is concerned with determining major tasks to be accomplished and finding suitable partners to be involved. A legal framework may be specified for contractual arrangement between the different partners. It is also necessary to plan and obtain the capital needed to support the VE.
3- ***Design.*** The newly formed VE is designed in detail for the information and material flow, process integration, and control systems. A mission database should be created to keep all information of the VE and its operations.
4- ***Operation.*** The VE operates using the resources, rules, and specifications established in the previous phases. To keep the right mix of skills and resources during the whole project duration, some alterations on the set of existing partners may occur. Therefore, it is likely

that some activities of formation and design phases will be performed during the operation phase.

5- ***Dissolution.*** The VE is dissolved when its mission is accomplished. Mission information should be distributed to all partners, and any assets acquired may be sold or re-deployed if partners want to pursue jointly another business endeavor. An entity will assume the responsibility to act as a VE representative to customers after its dissolution.

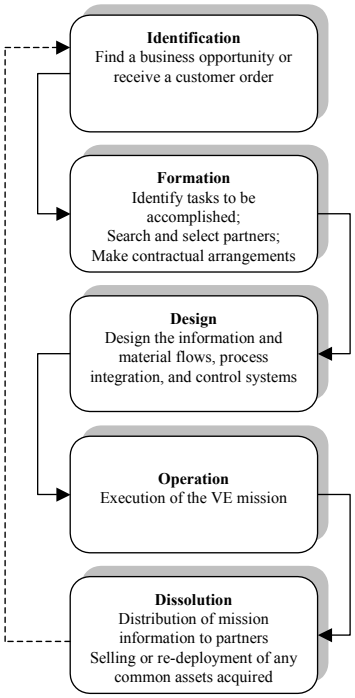

Fig.1. Virtual Enterprise life cycle

3 Problems related to Virtual Enterprise implementation

The implementation of the VE paradigm faces several problems requiring consideration at different levels of management and operations. One of the main issues is the heterogeneity and incompatibility between legacy systems of participating companies. As Camarinha-Matos (1997) points out, VE members are autonomous entities which typically pre-exist before deciding to join a VE and as such they legacy systems were designed independently of each other to serve the specific purposes of each one. Different enterprises have different control systems and usually contradictory views and semantics associated with the information they use.

Madni et al. (1998) state that when two or more organizations form a VE, their integration is far from seamless, with different types of mismatches and functional overlaps. Specifically, mismatches in their processes, data interfaces, technologies, information infrastructures, trading partner agreements, organizational structure, and best practice are not uncommon. These mismatches, if left undressed during formation phase, can greatly increase integration risks, with inevitable schedule delays and cost over-runs. However, these problems are invariably discovered once the VE has begun the operation and deficiencies begin surface. At this late stage, attempts to rectify problems are costly and complicated.

The way partners' business processes are organized and managed also faces some challenges. Managers of companies involved in VE need to be able to drive processes of their supply chain partners, and running these processes across advanced computer networks means unprecedented access to back-end IT systems (Binstock, 2000). To participate in a VE, companies must consider

the use of processes that allow intensive information sharing with partners, and at the same time preserve their confidential business information. The security issue is thus an important question to be addressed. Some private local information about an enterprise must not be confounded with information to be shared with the entire network for accomplishment of the common objectives.

According to Reid et al. (1996), to effectively manage manufacturing enterprises in the new environment, firms must understand how VE are formed, operated and dissolved. They must be able to execute the steps of this dynamic business cycle using both shared and individually owned processes and assets. This requirement implies a different process/asset management paradigm and suggests a need for enhanced process/asset management tools and techniques. However, Su and Poulin (1996) note that the management method for VE is complex because it must combine fluidity and control, strong partnership relations and short life cycle, differences and cohesion.

The ability to integrate with others must become a vital competence to succeed in a VE which requires integration that changes dynamically. Integration tools and technology will have to address the need to rapidly reconfigure integration infrastructure. Although many enterprise application integration (EAI) providers claim such dynamic support, much manual configuration is still required (Biggs, 2000).

Cultural and organizational aspects must not be neglected. When a VE is set up, partners will have more or less different cultures, viewpoints and methods of operation. Consequently, teams working in VE face challenges in operating effectively and staying focused on overall goals. Therefore, it is essential to continually reclarify and adjust the goals, objectives and strategies of the alliance. As Littlewood (1996) puts it, without clearly articulated common goals for the virtual team, the “old” goals of the individual components and individuals may set the team operating at cross-purposes and certainly erode effectiveness. Soft-side issues should be integrated in the process of managing performance.

The risks of opportunistic behavior between project partners as a function of unforeseen business events remains a critical point for VE which comprises little or no formal agreements between participants. Teams are often made up of strangers whose trustworthiness has not been clearly established. To cope with this aspect, Su and Poulin (1996) suggest an instrumental approach based on formal tools such as definition of a co-operation frame and organizational structure, as well as behavioral approach, concerned with trust building and loyalty between partners.

Legal issues are another question to be addressed in order to allow practical implementation of VE. The legal framework of the VE itself, namely in terms of establishment of members’ contracts, definition of roles, duties, authorities, and rights, as well as the legal aspects related to outsiders (other clients and suppliers, governmental organizations, etc.) need to be understood and supported (Camarinha-Matos and Afsarmanesh, 1998). However, the legal barriers and the need for re-organizational changes implying retraining of people and new roles assignment take time to implement and require a very careful approach.

4 Requirements for capacity management in Virtual Enterprises

Taking into account the characteristics and problems associated to VE, we will now propose a number of requirements for an efficient and effective manufacturing capacity management in a VE environment.

4.1 Functional requirements

Capacity modeling. To allow capacity analysis and planning to be performed, the capacity of the different production units in the VE needs to be appropriately translated into capacity models. This requires some form of interface to translate the 'real world' into a computer model. Each capacity model should provide a measure of the corresponding production unit capacity, support the creation of capacity plans, perform material management, and evaluate the implications of a given customer order.

Support for order promising. The efficiency of a VE depends on its ability to make immediate order acceptance with absolute commitment to due date, quantity and quality. And this requires order promising systems that take into account capacity availabilities across the whole VE network. Thus, when a request enters the VE at a given node (manufacturing plant), the system must check for its feasibility internally taking into account the capacities and plans of the node, and externally by forwarding the request to the next relevant nodes. The final answer to the customer is then fed back to the node where the initial request had occurred.

Local and global optimization. For streamlining manufacturing flows across the VE, and thus avoiding high levels of WIP and long lead times that frequently exist between individual units of a supply chain, capacity optimization in a VE must be performed at both local level and inter-company level.

Monitoring of production status. Since production plans of the VE members are highly interdependent, disruptive events occurring in one node can have a significant negative impact on the global plan if it is not identified and controlled in time. Therefore, an early warning mechanism is indispensable. However, for timely reaction to be taken it is necessary to have a system that can continuously monitor the execution of orders along the VE supply chain.

4.2 Non-functional requirements

Flexible and configurable capacity models. This need comes from the fact that significant differences may exist concerning the type, level of detail and amount of internal information that each node may make available to the VE. Another reason lies in the high heterogeneity which is likely to exist between the manufacturing systems of the individual companies.

Computational efficiency. Since one of the strategic goals of a VE is the capability to respond quickly to market demands, the use of elaborated but time-consuming methods may be counterproductive. Consequently, capacity planning systems for VEs must be able to make appropriate compromise between the quality of the solutions and the accuracy/run-time of the algorithms. Expedite approaches should be used whenever possible so that solutions with a reasonable degree of accuracy can be obtained in a relatively short-time frame.

Adaptive models. Stochastic events are difficult to predict at the level of inter-company manufacturing flows. Therefore, it is necessary to have capacity models which can easily adapt to unforeseen events affecting capacity resources (e.g., equipment breakdown) or the actual production conditions (e.g., alteration of product mix, delays in the execution of operations, shortages of materials).

Coordination. Owing to the autonomy and dispersion of the entities participating in a VE, the coordination of their individual plans and actions is fundamental. Therefore, a capacity management system in this environment must be able to effectively coordinate local capacity plans in order to allow a streamlined flow of materials within the VE.

Decentralized management. Owing to the distributed nature of manufacturing activities and the autonomy of the companies in a VE, global capacity management should be based on a decentralized approach that leaves as much responsibility for local control as possible to the individual manufacturing units.

Integration with other systems. Managing production in a VE at a global level requires information that is managed by heterogeneous legacy systems. Hence, capacity management tools for VE must have generic interfaces for integrating with the systems within individual companies.

5 Conclusion

Through a literature survey, this paper has attempted to make an overview of the understanding that exist on the VE concept. Although the various definitions of the VE differ somewhat, it seems there is a general agreement on its key characteristics. We also tried to identify a number of crucial issues, spanning different areas of management, which need to be addressed for a successful implementation of the VE concept.

Based on the characteristics and issues analyzed, important requirements for an effective and efficient capacity management decisions in VE environments were identified. Some of these requirements are concerned with the adaptability of capacity models, computational efficiency, monitoring mechanisms, support for distributed order promising, and integration with legacy systems. A subsequent work that we intend to carry out is to use the requirements identified to develop a planning tool for an accurate and real time capacity planning in a VE environment.

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